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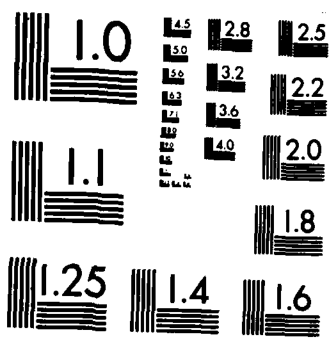

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TECHNICAL REPORT GL-84-14

ENGINEERING GEOLOGY OF SELECTED AREAS, US ARMY ENGINEER DIVISION, LOWER MISSISSIPPI VALLEY

Report 1
THE AMERICAN BOTTOM AREA, MO-IL
VOLUME I

by

Lawson M. Smith, Fred L. Smith

Geotechnical Laboratory

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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION · CE ·

December 1984
Report 1 of a Series

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This report is the first in a series of four reports describing the engineering geology of selected areas in the US Army Engineer Division, Lower Mississippi Valley area. The purpose of the report is to characterize the geotechnical parameters of the American Bottom area in the vicinity of East St. Louis, Illinois, and Missouri. The area encompassed is equivalent to 15 min of longitude and latitude, and is covered by portions of the Granite City, Monks Mound, Cahokia, and French Village 7.5-min US Geological Survey

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20. ABSTRACT (Continued).

quadrangles. Geotechnical parameters of the study area were determined from existing data, including engineering and water well borings, aerial photography, soil, geologic and topographic maps, and published and unpublished reports and field notes.

Geotechnical parameters selected for mapping and analysis include physiography, surface geology, subsurface geology, surficial soils, land surface slope, surface drainage, and sources of construction materials. Each parameter, or factor, is portrayed as a transparency for overlay on the map of the surface geology, enabling the simultaneous visual analysis of several geotechnical parameters. Of particular importance to engineering projects are the engineering properties of the various surficial soils, mapped by geologic environments and shown on the surface geology map. Relevant engineering properties of soils which occur in abandoned channels, point bars, chutes and bars, backswamps, alluvial fans, tributary valleys, and loessial uplands are given. The occurrence of ground water in the area and its influence on engineering projects is discussed.

Plates 1-11 for this report appear in Volume II.

PREFACE

This report is the first in a series dealing with the Engineering Geology of Selected Areas in the US Army Engineer Division, Lower Mississippi Valley (LMVD). The study was authorized in October 1980 by the LMVD and jointly funded by the US Army Engineer Districts, St. Louis, Memphis, Vicksburg, and New Orleans.

This study was conducted in the Geotechnical Laboratory (GL) of the US Army Engineer Waterways Experiment Station (WES). The investigation was performed during the period 1 October 1980 to 1 October 1981 under the direct supervision of Mr. J. H. Shamburger, Chief, Engineering Geology Applications Group (EGAG), Engineering Geology and Rock Mechanics Division (EGRMD), GL, and under the general supervision of Dr. D. C. Banks, Chief, EGRMD, and Dr. W. F. Marcuson *III*, Chief, GL.

The report was written by Dr. L. M. Smith and Mr. F. L. Smith, EGAG. The data collection and preparation of the maps were performed by Dr. L. M. Smith and Messrs. F. L. Smith and J. R. May, EGAG. Table 1 was prepared by Mr. P. G. Tucker, Engineering Group, Soil Mechanics Division, GL.

Suggestions and guidance provided during the study by Messrs. F. J. Weaver, T. H. Riddle, L. H. Cave, and W. M. Myers of the LMVD are greatly appreciated.

The Commanders and Directors of WES during the conduct of the study and preparation of the report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. The Technical Director was Mr. Fred R. Brown.

CONTENTS

* In Volume II.

CONVERSION FACTORS, US CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

US customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
gallons (US liquid)	0.003785412	cubic metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
square feet	0.09290304	square metres

ENGINEERING GEOLOGY OF SELECTED AREAS, US ARMY ENGINEER DIVISION, LOWER MISSISSIPPI VALLEY

THE AMERICAN BOTTOM AREA, MO-IL

PART I: INTRODUCTION

Background

1. In 1957, the US Army Corps of Engineers (USACE) initiated a program to identify the nature and distribution of alluvial environments of deposition within the Lower Mississippi River Valley. The purpose of the project was to provide needed geological data at a scale of 1:62,500 that could be applied to various phases of USACE projects. Since this initial effort, over 200 quadrangle maps have been published covering almost the entire Lower Mississippi River Valley and a part of the Mississippi River Deltaic Plain. Each quadrangle delineates the natural levee, point bar, backswamp, abandoned channel, abandoned course, and related depositional environments and is accompanied by two or more subsurface profiles. These profiles identify the lithology of the Holocene alluvium in terms of the upper fine-grained topstratum portion and the lower coarse-grained substratum and the underlying Pleistocene or Tertiary deposits.

2. Studies conducted by the US Army Engineer Waterways Experiment Station (WES) in the 1960's (Kolb et al. 1968, Fleetwood 1969, Saucier 1964, 1967, 1969, Smith and Russ 1974, Smith and Saucier 1971) established correlations between engineering properties of fine-grained cohesive soils and depositional environments within the alluvial and deltaic plains of the Lower Mississippi River Valley. These studies established important relationships and trends within the specific depositional environments of the material types studies. Study reports recommended that such correlations be continued and extended to other depositional environments. Similarly, studies conducted for the Federal Highway Administration in the States of New Jersey, Delaware, and Rhode Island established that geologic subdivisions could be successfully developed to provide correlations with engineering properties of geologic materials other than alluvium. These latter studies also grouped and delineated areas of similar engineering characteristics on a series of maps.

3. Geologic and engineering parameters, including the geological origin, composition, and description of surface and subsurface soils and rock types, physiography, material properties, and an engineering assessment of suitability of the materials for highway construction (e.g., cuts and fills, and embankment and borrow) were identified on the maps by symbols. Although these studies were made for use by highway planners, design and construction engineers and geologists have found these surveys extremely useful in site selection studies, development of exploration programs, identification of problem areas, location of construction materials, and assessment of groundwater conditions as related to construction operations. Therefore, a pilot program was authorized by the US Army Engineer Division, Lower Mississippi Valley (LMVD) to perform an engineering geological characterization study of four quadrangles within their area of responsibility.

Purpose

4. The purpose of this pilot study is to characterize the geological, soil, and other parameters of selected areas in terms that will be used by the planners, design and construction engineers, and geologists in site selection studies, the development of exploration programs, identification of problem areas, and location of construction materials. Correlations between geological and engineering data were made to improve the understanding between geologic and engineering characteristics of soils in alluvial and nonalluvial areas.

Scope

5. This study is part of a larger investigation including the areas encompassed by four 1:62,500-scale quadrangles, one in each of the four districts within the LMVD. The characterization of the selected engineering and geologic parameters was accomplished by assembling and analyzing existing data (no new field data were collected) and presenting these parameters on a map with overlays (plates), which are presented in Volume II of this report, and figures and tables, which are contained in Volume I.

Methodology

6. The methodology employed in the study included six steps: (a) selection of geologic or geologic-related parameters or factors that have engineering significance; (b) selection of study areas that encompass a variety of conditions or that are of particular interest to the LMVD; (c) collection of available data; (d) analysis of data to establish correlations between geologic conditions and engineering characteristics; (e) construction of a series of maps or overlays for each of the selected parameters and compilation of appropriate table(s); and (f) development of a narrative to accompany the plates and figures. Each of the four study areas are presented as individual reports. This report presents the results of the study of the American Bottom Area (vicinity of St. Louis), MO-IL, in the St. Louis District.

PART II: DATA COLLECTION AND MAPPING PROCEDURES

Identification of Parameters

7. The process of selecting the appropriate engineering-geology parameters involved reviewing published reports of similar studies conducted by state and federal agencies and discussions with engineers and geologists in the LMVD office and in the four LMVD Districts. The list of appropriate parameters generated from the above effort was compared with the availability of data and state-of-the-art interpretative techniques before final selection was made. The parameters selected for mapping and analysis were physiography, surface geology (depicted on a map and several cross sections), subsurface geology (top of sand and gravel, top of Paleozoic), engineering soils, slope, and drainage. Descriptors or classes were selected for the above parameters.

Sources of Data

8. A search was conducted to locate available topographic, hydrologic, engineering, soils, and geologic information related to the study area. Pertinent literature in the form of maps, reports, etc., were obtained and reviewed, and relevant data were abstracted for inclusion in the study. Subsurface data such as logs of engineering borings and water wells were collected from the US Army Engineer District, St. Louis, the Illinois State Geological Survey, the Illinois State Water Survey, the Illinois State Highway Department, and private engineering firms. Surface soil maps were also acquired for the counties in the study area from the Soil Conservation Service, US Department of Agriculture (USDA). Aerial photographic coverage of various dates and scales was acquired to assist in mapping the surficial geology. Topographic map coverage was obtained for the study area from the US Geological Survey (USGS). All data collected for this study are contained in permanent files of the Engineering Geology Applications Group (EGAG), Engineering Geology and Rock Mechanics Division, Geotechnical Laboratory (GL) at WES.

Mapping Procedures

9. Preparation of plates outlining the limits of each engineering-geologic parameter was based on information gained from interpretations of

features obtained from aerial photographs, published maps and reports, and/or logs of available borings.

Physiography and topography

10. The topographic map was prepared by combining Granite City, Monks Mound, Cahokia, and French Village, Illinois, 7.5-min (1:24,000) topographic quadrangles (Plate 1).* These four quadrangles were then reduced to a 15-min (1:62,500) scale map. Physiographic boundaries were then compiled from published maps and adjusted to scale (Plate 2).

Surface geology

11. The surface geology map (Plate 3, intended to be used as a base map for overlaying all factor maps) was prepared by studying and mapping surface features on topographic maps and individual aerial photographs and photomosaics ranging in scale from 1:10,000 to 1:62,500. The surface features (landforms) delineated on the photography were mapped according to their depositional environments. A discussion of each depositional environment is presented in Part III. Characteristics of each surface unit were then compiled from all sources and identified on a transparent 1:62,500-scale overlay.

Subsurface geology

12. The geologic units that were mapped in the area ranged in age from Mississippian to Recent. The stratigraphy of the study area is presented in the form of a stratigraphic column (Plate 4) which was compiled from published reports. The range of thickness, lithology (columnar section), and a description of each geologic unit is compiled from studying boring logs and from published literature. Time stratigraphic and lithostratigraphic units are based on terminology used by the Illinois State Geology Survey (Willman and Frye 1979, l

13. The nature of the subsurface geology was determined from engineering and water well boring logs that were collected from state and Federal agencies and from private engineering firms. Additionsl boring logs were extracted from published reports. The boring locations were plotted on a transparent overlay and are shown in Plate 5. Applicable borings were used to construct surface and subsurface profiles throughout the study area. Profile locations are also shown in Plate 5. The vertical and horizontal relationships of the geologic formations encountered along the profiles are shown in sections in Plate 6.

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* All plates are contained in Volume II.

recompacting this material (see discussion of loess above). Particular attention should be given to water content and thickness of lifts of the material being compacted.

trata. Most producing water wells in the Springfield Till Plain range from ;0 to 200 ft in depth and produce less than 20 gallons per min. West of he Americal Bottom, piezometric levels in the Salem Plateau vary similarly o those of the Salem Plateau east of the Mississippi River. Limestone strata nder St. Louis are highly fractured, with much solution by groundwater occurring in fractures. The depth to the piezometric surface may vary from 70 to 0 ft in the Salem Plateau region. Current data on groundwater conditions can e obtained through the Illinois State Water Survey, the Missouri Geological urvey, and the USGS.

39. High ground-water tables may impose substantial dewatering problems o some foundation requirements. This condition is especially true for sites ituated on chutes and bars or point bar environments adjacent to or within everal miles of the Mississippi River, environments which experience substantial seasonal fluctuation of groundwater levels (which roughly parallel Mississippi River stages). The permeability of the alluvial fill in the American Bottom increases with depth through the Cahokia alluvium into the Henry outwash.

Construction Materials

40. Primary sources of construction materials within the study area are found in the Mississippi River floodplain and along the Illinois bluff. The sand and gravel deposits within the Mississippi River floodplain, usually lying 10 to 40 ft beneath the fine-grained topstratum deposits, are an excellent source of aggregate. Sand predominates in these deposits, while gravel is found at depths generally exceeding 60 ft. Most of the sand and gravel obtained in the area is dredged from the Mississippi River channel. The fine-grained material (topstratum deposits) above the sand and gravel usually is suitable as borrow material. Some gravel deposits are found in uplands but the deposits appear to be localized. Thick limestone deposits occur in the Illinois bluff south of Cahokia, Illinois, and east of Dupo, Illinois. Two large quarries are located in Sections 14 and 27, T1N, R10W. These limestone deposits (mapped as the karst area) are relatively thick (200 plus ft), have a gentle slope, and extend 2-1/2 to 4 miles eastward away from the bluffs. The loess deposits that cover most of the uplands can be used as material for foundations and road fills. However, extreme care should be used when

systems control surface drainage. Most of the Mississippi River floodplain is within a flood protective area created by artificial levees and railroad embankments. The drainage divides of the tributary streams in Illinois Uplands are delineated in Plate 11.

Ground Water

37. The quantity and quality of ground water is highly variable. The nature and relationship of the geologic formations exert an important control over the occurrence, quantity, and quality of ground water. Excellent water-yielding sand and gravel deposits (the substratum) are present in the Mississippi River floodplain. These aquifer materials are generally present below a depth of 20 to 50 ft. That part of the floodplain relatively near the Mississippi River is particularly suitable for the development of high-capacity wells. Conditions are favorable in most areas along the river for groundwater recharge from the river. The floodplain areas along the Illinois bluff is less favorable for the development of high yield wells due to the thinning and discontinuous nature of the substratum deposits. Wells in the upland loess deposit are generally unproductive and yield low amounts of water. Wells penetrating the rock units are extremely variable in productivity because the water is localized in fissures in the bedrock.

38. The elevation of the piezometric surface is extremely variable in time and in space. Within the American Bottom, the piezometric surface may occur at depths of 10 to 50 ft, depending on the time of year, recent discharge stages of the Mississippi River and local streams, the nature of the aquifer (lower Cahokia and Henry Formations) and the overlying fine-grained alluvial topstrata, and the rate and extent of localized pumping. In the Salem Plateau region east of the American Bottom, the piezometric surface generally occurs in the fractured limestones beneath the overlying loess. Elevation of the piezometric surface in the Salem Plateau may vary from approximately 60 to 200 ft below the surface, depending on the frequency and magnitude of fractures in the limestone, proximity to the bluff line (where springs emerge from large fissures in some areas), and seasonal precipitation. Piezometric levels in the Springfield Till Plain usually occur beneath the relatively thin overburden of Pleistocene loess and glacial till and is highly variable, depending on the existence of highly fractured shales and permeable sandstone

33. Alluvial fans. Soil types comprising the alluvial fans (dashed line symbol next to the Illinois Uplands) are predominantly silty clays (CL) and silts (ML). The unusually fine-grained texture of the alluvial fans, together with their low surface slopes (1-2 deg) reflect their fine-grained source material, loessial silt. These alluvial fans vary considerably from the coarse-grained, steep alluvial fans found along mountain fronts in arid regions.

Upland soils

34. The uplands are covered with aeolian silts (Peoria loess deposits of late Pleistocene age) except where the surface is deeply incised by streams. The soil types found in these deposits are silts (ML) and silty clays (CL). Underlying the Peoria loess are glacial tills containing mixtures of sand, gravel, silt, and clay and several additional loessial deposits. A more complete description along with stratigraphic position is given in the stratigraphic column (Plate 4).

Topography and Slope

35. The combined influence of local geomorphic processes and surficial geology has resulted in a wide variety of topographic expression. The topography varies from nearly flat in the Mississippi River floodplain to highly dissected hills and ridges in the uplands. Five classes of slopes depicting various stages of relief are mapped in Plate 10. These slopes range from less than 2 percent (nearly flat, class 1) to greater than 20 percent (very steep, class 5). The middle ranges are 2 to 5 percent (class 2), 5 to 10 percent (class 3), and 10 to 20 percent (class 4). The Mississippi River floodplain falls predominantly within the class 1 category with occasional areas of class 2 slopes scattered in the area. The uplands in the Missouri side of the study area fall largely in the class 2 or 3 slope category with occasional areas class 4 slopes occurring. The Illinois uplands are more rugged and irregular with slopes being evenly distributed between classes 2 to 5.

Drainage

36. Natural drainage has been greatly altered by man in the last 150 years. For the most part, the larger natural streams in the American Bottom have been channelized or realigned. In urban areas, artificial drainage

becomes slightly compacted by the weight of succeeding overlying flood deposits. After the channel has been completely filled, seasonal lowering of the ground-water table permits partial drying and drainage of the upper part which becomes denser than the portion below the ground-water table. Soil types found in abandoned channel deposits vary from sand-silt mixtures (SM) (prevalent in the neck area) to highly plastic clays (CH) (dominant in the bendways). The predominant sediment or soil type found in an abandoned channel is fat clays (CH) or map unit 8.

30. Backswamp. Backswamp areas also reveal distinct depositional conditions. Sediments within these areas occur as thin layers from floodwaters that periodically fill the flood basin. After each flood subsides, the surficial layer of sediments undergoes dessication and oxidation. Subsequent floodwaters cause additional sedimentation, alternating wetting and drying, sealing of cracks, and development of characteristic color and structure leaving the backswamp deposits with a lower water content than the abandoned channel deposits. The soil types found with backswamp deposits range from sand-silt mixtures (SM) to fat clays (CH). The predominant soil type in the backswamp environment is silty clay (CL) or map unit 6.

31. Point bar. Point bar areas in the American Bottom are formed by lateral migration of the Mississippi River. Point bar deposits extend as deep as the thalweg of the river and can be separated into a fine-grained topstratum and a coarse-grained substratum sand and gravel. Within the topstratum, there are two types of deposits: silty and sandy, elongate bar deposits or ridges which are laid down during high stages of discharge, and silty and clayey deposits in arcuate depressions or swales which are deposited during flood recession. Soil types associated with point bar areas range from silty sands (SM) to fat clays (CH). The predominant soil type in the ridge area is a sand-silt mixture which may be classified as silty sands (SM). In the swale areas silty clays and fat clays (CL/CH) predominate.

32. Chutes and bars. Chutes and bars are formed similarly to point bars, except that the bars frequently experience inundation by flood discharges of sufficient velocity to cause considerable scour and deposition locally. The resulting deposit has a more irregular surface topogaraphy than a point bar and generally fines upward texturally from sand and gravel (GP) at the base through silty sand (SM) to a highly irregular topstratum of sand (SP) or silty sand (SM) ridges (bars) and silty clay (CL) and clay (CH) filled chutes in the topstratum.

miles apart in the southwestern portion of the quadrangle. As indicated on the map, the Mississippi River is not flowing in the deepest part of the valley, but is impinged against the eastern flank of the Salem Plateau. The greatest entrenchment of the valley occurs in the eastern half of the American Bottom. An elevated rock bench occurs in the Mosenthein Island area. The shallow resistant bedrock in this area has impeded the vertical incision of the Mississippi River, which in turn adjusted its channel by widening and building Mosenthein Island. The shallow depth of the river necessitated the excavation of Chain of Rocks Canal.

d. Upland deposits. Rock in the uplands is primarily Mississippian limestone and/or Pennsylvanian shales with sandstone lenses. Overlying these sediments are several glacial till and aeolian loess deposits. A detailed description of each unit is given in Plate 4.

Soils

27. The surface geology, topography, and the physical properties of soils play an important role in determining the suitability of areas for siting engineering structures. The soil types that cover the Mississippi River floodplain and the uplands within the study area can be related to their mode of deposition (alluvial, glacial, aeolian), and type of materials (sand, clay, silt, etc.) which were deposited in each environment. Sediments overlying the Mississippian and the Pennsylvanian rock in the Mississippi River floodplain and the uplands within the study area vary in thickness from a few feet to as much as 150 ft (Plates 6 and 8). The distribution of surficial soils within the study area are shown in Plate 9. The soils are separated into eight map units. Four of these units have a dual classification with the dominant type listed first.

Floodplain soils

28. As stated above, the unconsolidated soils in the Mississippi River floodplain can be separated into a basal coarse-grained sand and gravel and a fine-grained topstratum. The characteristics of the alluvial topstratum are determined principally by their depositional environment. Each depositional environment is characterized by a discrete set of transport and depositional processes, which dictate the texture and geometry of the resulting deposit.

29. Abandoned channels. This environment consists of mostly fine-grained sediments introduced into an abandoned channel during various periods of flooding which accumulate slowly and usually in thin layers. Each layer

Creek Valleys. Because of their relative insignificance and lack of data, their engineering characteristics were not determined.

Subsurface Geology

26. Numerous water wells and engineering boring logs were collected to determine the boundaries and subsurface distribution of depositional environments and geologic formations in the study area. Location of these borings and geologic profiles across the area are shown in Plate 5. The profiles (Sections A-A' and B-B') were constructed using the boring data to show the vertical and lateral relationships of the specific alluvial environments and geologic formations in the Mississippi River floodplain, tributary valleys, and the Illinois bluff (Plate 6).

a. Mississippi River floodplain deposits. The filling of the Mississippi River entrenched valley (as depicted in Sections A-A' and B-B') has been ongoing since at least the Wisconsinan stage of the Pleistocene epoch. The basal alluvial unit (Henry Formation) overlying the Mississippian rock is a heterogenous mixture of sand and gravel and is considered to be glacial outwash. Overlying the Henry Formation are the Holocene deposits (Cahokia Formation) of the Mississippi River, which may be divided into a fine-grained topstratum of clay, silt, and silty sand and a substratum of sand and gravel. On the basis of environments of deposition and general sedimentary characteristics, the topstratum may be subdivided into abandoned channel, point bar, chutes and bars, and backswamp deposits (Plate 6). Segments of 26 abandoned Mississippi River channels are mapped and undoubtedly are the most outstanding feature in the American Bottom (Plate 3). The Pittsburgh Lake channel section on Section B-B' is a detailed cross section of a typical abandoned channel, emphasizing the variability of soils found in this particular environment.

b. Elevation of substratum sand and gravel. The top of sand and gravel is the base of the topstratum. Contour lines, based on subsurface data, are expressed in feet (mean sea level) and are dashed, indicating th ir approximate nature. The trend of the contours follows the abandoned channel deposits with the thin topstratum deposits usually found in the point bar areas and the deeper sand and gravels in the bendways of the channels. The thickness of the fine-grained topstratum in the American Bottom region of the study area is the difference in elevation between Plates 1 and 7.

c. Elevations of rock subcrop. Elevation in feet msl, of the rock surface underlying the study area is shown in Plate 8. The top of rock varies in elevation from slightly less than 275 ft msl to just above 625 ft msl. These points occur only about two

i. <u>Rock.</u> Local outcrops of rock occur along the Illinois bluffs and steep tributary valley walls. Specific information has not been delineated on the map (Plate 3) since several formations often occur at each outcrop. The local stratigraphic diversity of rock outcrops in the region may be seen in the stratigraphic column (Plate 4). Generally, Mississippian age limestones outcrop along the bluff south of Prairie duPont Creek and softer Pennsylvanian shales outcrop to the north. Erosion of the softer shales by lateral migration of the Mississippi River has resulted in valley widening in the East St. Louis area. The Mississippian limestones and dolomites of the area are a substantial source of aggregate and riprap materials. In the immediate area, six quarries and two underground mines have been developed to exploit the local limestone and dolomite sources. Most of the production comes from the upper St. Louis Limestone or St. Genevieve Limestone. The oolitic limestone in the St. Louis and St. Genevieve Limestones have been used in various types of structures as a building stone.

j. <u>Loessial uplands (Peoria Formation).</u> As previously mentioned, the occurrence and thickness of unconsolidated materials differ considerably between the Missouri and Illinois Uplands. The stratigraphy of the Illinois Upland is especially complex, consisting of surficial clayey silt (Peoria Loess) which may be underlain by several additional formations of silt (probably loessial) and glacial till, which is highly variable and usually unsorted in particle size (Figure 8). A detailed description of each formation is presented in Plate 4. The unique nature of loess gives it correspondingly unique engineering characteristics. Due to its high moist-to-dry strength, vertically oriented internal structure, and carbonate cementation, loess will stand on almost vertical cuts. However, vertical shear failures may occur where excess moisture is allowed to infiltrate the top of the excavation. When loess is remolded and when used as fill, the density of the material is usually increased about 10 percent, but the natural characteristics which give it strength in an undisturbed condition are lost. Accompanying the increase in density during remolding, the permeability is decreased and the silt-sized particles are easily eroded when exposed to precipitation or surface flow.

k. <u>Lacustrine (Equality Formation).</u> During the last glacial advance, the Mississippi River, choked with outwash from glaciers to the north, aggraded its floodplain to an elevation at least 40 ft higher than the present floodplain. Tributary valleys such as Prairie duPont Creek were blocked by the Mississippi River outwash and backed up to form lakes where fine-grained sediments (silts (ML) and clays (CL-CH)) accumulated in them. After the glaciers withdrew and the amount of sediment introduced to the upper Mississippi River decreased, the river began to remove the outwash through incision and lateral migration, eventually removing tributary blockages, and allowing the tributaries to remove most of the lacustrine deposits. The only glacial lacustrine deposits mapped in the study area occur in several very small areas of the lower Prairie duPont and Canteen

periods of stream flooding and consist of a relatively thick deposit of clay (CH), silty clay (CL), and silt (ML) over a previously existing deposit (Figure 5). The floodwaters carrying sediment to this environment are ponded between natural levee ridges on separate meander belts or between natural levee ridges and the uplands. The backswamp deposits in the study area are quite possibly underlain at shallow depths by glacial outwash deposits (Henry Formation) from the last glaciation. The fine-grained materials of backswamps exhibit fair unconfined compressive strengths suggesting a moderate suitability for foundations of most types.

e. Alluvial fans, colluvial aprons (Peyton Formation). At the base of the Illinois bluff, fan-shaped deposits of sandy silt (ML) are formed by tributary streams exiting the bluff onto the Mississippi River floodplain. The fans radiate outward from the mouths of the upland valleys. Unlike the classical alluvial fans of more arid regions, these fans do not necessarily coarsen in texture upward or up-fan. As a topstratum deposit, they are relatively coarse-grained, usually consisting of redeposited loessial silts (ML) with lenses of sand (SP) and silty clay (CL) (Figure 6). Where they have formed extensively, they have coalesced into an alluvial apron. In areas where the river has recently migrated against the bluff, existing fans have been removed and an apron of colluvium resulting from mass-wasting of the bluff face has accumulated. Alluvial fan environments are moderately well suited to most foundation requirements due to moderate soil strengths, low water contents, and good drainage.

f. Undifferentiated alluvium (Cahokia Formation). At the base of the Missouri bluffs, an extensive area is mapped as undifferentiated alluvium. The type of alluvium was not differentiated due to extensive coverage by urban land use and the probable existence of widespread artificial fill. Where undisturbed, the underlying material is probably of the chutes and bars environments.

g. Tributary valley alluvium (Cahokia Formation). The stream valleys of the larger tributaries are partially filled with alluvium derived from local formations. The alluvium generally grades upward from sand (SP) with gravel to silty clay (CL) and is often underlain by one or more glacial till formations (Figure 7). Relatively low unconfined compressive strengths and intermediate water contents reveal potential problems for certain foundation conditions.

h. Substratum deposits (Henry Formation). Underlying the different alluvial deposits of the Cahokia Formation in the American Bottom are 40 to 60 ft of glacial outwash, consisting of sand and gravel (GP, GW) roughly grading upward to an uppermost sand (SP) or silty sand (SM), with an occasional silty clay (CL) strata capping the unit. The Henry rests unconformably on the bedrock valley of the Mississippi River and is the primary aquifer in the American Bottom.

a. Abandoned channel (Cahokia Formation). Abandoned channel deposits are the result of gradual infilling of lakes formed by the lateral migration of the Mississippi River. A typical sequence of abandoned channel deposits consists of a thin (5 to 10 ft) basal strata of sand and gravel (GP, GW) grading rapidly upward to sand (SP) and silty sand (SM), and overlain by a relatively thick (40 to 50 ft) sequence of lenses of fine-grained material, predominantly clay (CH) and silty clay (CL) with occasional silt strata (ML). The thickness of fine-grained deposits is generally greatest near the outside (cutbank) edge of the abandoned channel at a point most distant from the points of abandonment (ends of the abandoned channel). The total thickness may exceed 75 ft, with the fine-grained portion reaching 60 ft in depth (Figure 2). These relatively thick fine-grained deposits often exhibit severe foundation problems due to excessive wetness, low strengths of materials, high compressibility, difficulty of compacting, and a high shrink-swell potential.

b. Point bar (Cahokia Formation). Point bars are lateral accretion deposits which are formed during the horizontal migration of stream channels. The stream migrates laterally by building a lateral bar of silt (ML) and sand (SP) on its inside (point bar) bank, shifting to the outside (cut) bank through periodic failure of the outside bank. The construction of a series of lateral bars results in a corrugated surface of silty sand (SM) ridges and alternating clay (CL and CH) filled depressions or swales (Figure 3). Point bar deposits are generally separated into a fine-grained topstratum (clays, silts, silty sand) and a coarser grained substratum (sand and gravel). The topstratum deposits are relatively thin and have a better bearing capacity than the abandoned channel deposits, indicated by high unconfined compression strengths and low water contents. Shrinking and swelling of clayey soils may be a problem in swale areas due to the significant fluctuation of local groundwater levels.

c. Chutes and bars (Cahokia Formation). The chutes and bars environment is formed in a similar manner to the point bar deposits, except that the surface frequently experiences inundation by floodwaters of relatively high velocity which may cause considerable scour and deposition locally. The resulting deposit usually grades upward from sand (SP) and gravel (GP) through sand to a highly irregular topstratum of silty sand (SM) ridges (bars) and deep silty clay (CL) to clay-filled (CH) chutes (Figure 4). The fine-grained chutes may be of considerable thickness (50 ft) and may exhibit foundation problems similar to those of the abandoned channel, although their horizontal extent is much less. In typical localities of chutes and bars, the chutes are on the order of 25 to 30 ft thick and contain CH and CL soils of moderate to slight compressibility, as indicated by fair unconfined compressive strengths and intermediate water contents.

d. Backswamp (Cahokia Formation). Backswamp deposits consist of fine-grained sediments laid down in broad shallow basins during

bedrock is considerable (up to 150 ft); consequently, the topography strongly reflects the specific age and nature of the soils. Generally, the local relief disappears (eastward) from the bluff as the thickness of the easily erodible loessial silts decreases. In the Salem Plateau section of the Illinois Uplands south of Stolle, the surface is potmarked by numerous sinkholes, a characteristic of karst topography. The development of the sinkholes, caverns, and subterranean drainage of the area is due to the existence at shallow depths of a dense, highly fractured, thinly bedded limestone (St. Louis Limestone), a subterranean outlet (springs along the bluff), and a generous amount of rainfall.

24. Repeated cycles of vertical incision, aggradation, and lateral migragion by the Mississippi River is responsible for the formation of the American Bottom, the largest physiographic section in the area. During the waxing and waning of the numerous ice sheets of the Pleistocene, the Mississippi River responded dramatically, aggrading and becoming braided during the glacial stages and degrading (somewhat) and meandering during interglacial stages. As the river migrated laterally, the periodic abandonment of channels occurred, stranding the former meanders as arcuate oxbow lakes.

Surface Geology and Environments of Deposition

25. The distribution of the surface geology was mapped on the basis of mode of deposition (alluvial, aeolian, and lacustrine) as presented in Plate 3. A stratigraphic chart of the area, based on terminology used by the Illinois State Geological Survey, is presented in Plate 4. The Holocene age alluvial sediments are separated into seven invironments of deposition which include abandoned channel, point bar, chutes and bars, backswamp, undifferentiated alluvium, and Tributary Valley alluvium (all of the Cahokia Formation); the seventh environment is the alluvial fans or colluvial aprons (Peyton Formation) located in the floodplain next to the Illinois bluffs. Aeolian deposits (Peoria Formation) cover the uplands in Missouri and Illinois and are designated as loessial uplands on the map. Lacustrine deposits (of minor geographic extent) are mapped as the Equality Formation. Typical soil profiles of major environments of deposition are presented in Figures 1-8 with Figure 1 being a definition of symbols and terms used in the other figures. The location of areas shown in Figures 2-8 are presented in Plate 5. A general description of each geologic environment is as follows:

PART III: ENGINEERING GEOLOGY

Physiography

20. The study area lies within two physiographic provinces, the Ozark Plateau to the west and the Central Lowland to the east. The Missouri side of the quadrangle and a small portion of the bluffs south of Stolle, Illinois, lie in the easternmost extremity of the Salem Plateau (of the Ozark Plateau). The Springfield Till Plain (of the Central Lowland) makes up the eastern portion of the study area. The Springfield Till Plain has been masked by loess deposited during the Pleistocene epoch. Incised into the Salem Plateau and the Springfield Till Plain is the valley of the Mississippi River, partially filled with alluvium and locally known as the American Bottom (Plate 2).

21. The Mississippi River floodplain, ranging from 150 to 200 ft below the crest of uplands, varies in width from 4 to 12 miles and, in most places, is separated from the uplands by an abrupt escarpment or bluff. Elevations of the floodplain range from 425 ft mean sea level (msl) at the northern boundary to 400 ft msl along the south edge of the quadrangle which results in a floodplain slope of approximately 1.4 ft per mile. Upland elevations in Illinois vary from 550 to 600 ft msl with the higher areas located near the escarpment where the loess deposits are normally the thickest.

22. The surface expression of the local geology is a function of geologic processes which have been operating in the region during the last several million years (Pleistocene epoch). On the Missouri side of the river (the Salem Plateau section), the surface generally reflects the contours of the bedrock. The present topography, consisting of low hills with broad divides, is developed primarily on thick Mississippian limestone which is overlain by several feet of sandy, gravelly clay (glacial till, possibly Kansan in age) and 10 to 26 ft of silt and silty clay (predominantly Peoria Loess and Roxana Silt). Sporadic locations of other unconsolidated sediments known as the Grover Gravel and the cherty, gravel residuum (tentatively correlated to the Nebraskan glaciation by Goodfield 1966) may occur beneath the Kansan glacial till and above the local bedrock.

23. The Illinois Uplands (predominantly Springfield Till Plain) have been strongly influenced by glacial advances and retreats during the Pleistocene. Unlike the Missouri Uplands, the depth of unconsolidated materials over

the slope of an area is less than the upper limit of the mapping unit represented by the diameter of a circle. Therefore, the area was mapped with the appropriate unit. Following this procedure, the four basic quadrangles (1:24,000 scale) were mapped and color coded according to appropriate mapping units. Numbers (1-5) were then assigned to each slope unit (1 being less than 2 percent slope and 5 being greater than 20 percent slope). The data were transferred to a transparent overlay and reduced to a 1:62,500 scale map.

Drainage

18. The drainage map (Plate 11) was prepared from the topographic map by identifying the drainage divides (the boundary between drainage basins). After these lines were drawn, each basin was identified by the name of the principal stream within each basin (Plate 11).

Sources of construction material

19. Sources of construction material are identified in Plate 9 (surficial soils) and consist predominantly of known quarries, rock outcrops, and borrow pits (sand and gravel). The soil units identify locations where specific soil types occur for selecting borrow material.

14. Contours for top of sand and gravel and Paleozoic rock were constructed after stratigraphic boundaries were determined from boring logs located throughout the study area. After the stratigraphic boundaries were identified, the elevations were plotted according to boring location, and a contour map was prepared depicting the subsurface configuration of the deposits. Plate 7 shows the top of sand and gravel or bottom of the fine-grained material within the Mississippi River floodplain. Plate 8 shows the top or surface of the Paleozoic bedrock throughout the study area.

Soil

15. The surficial soil map (Plate 9) was compiled from the USDA soil surveys of St. Clair and Madison Counties, Illinois (USDA 1978, 1980) and aerial photo interpretation. Data from the soil survey maps and aerial photo interpretation were combined to develop a single soil map which was reduced in size to match the 1:62,500-scale base map. The USDA textural types appearing on the map were then converted to the Unified Soil Classification System (USCS) equivalent (i.e., SM, CL, etc.). The soils were then grouped into eight categories based on USCS classification (unit 1 being the coarsest textured and unit 8 the finest textured) and delineated on the map of surficial soils.

Slope

16. The slope map (Plate 10) was compiled by manipulating a template over the 1:24,000-scale topographic quadrangles of the study area. This template consists of five circles of varying diameter each having a diameter corresponding to the upper limit of a slope mapping unit. The diameter for each of the circles was determined by computing the distance between adjacent contours required to obtain the maximum degree of slope for each of the mapping units with an elevation rise of 10 ft.* This distance is then converted to the mapping scale.

17. The preparation of the slope map consisted of scanning the topographic quadrangles and visually determining areas where the lowest slope values (widest spaced contour lines) occur, i.e., the area within the Mississippi River floodplain. Once these areas were noted, the circles on the template were manipulated between neighboring contour lines to determine the local slope class. The template was manipulated until the largest diameter circle could be placed between adjacent lines. This fitting process established that

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* A table of factors for converting US customary units of measurement to metric (SI) units is presented on page 3.

PART IV: ENGINEERING GEOLOGY SOIL CHARACTERISTICS

41. The previous sections have revealed the various engineering-geologic factors, the mapping processes, the geologic processes that have resulted in the formation of specific landforms, and some engineering characteristics of each landform (Figures 2-8). Tables 1, 2, and 3 were prepared to give the user additional engineering characteristics of the soils and their occurrence within specific soil units or landforms. Tables 1 and 2 deal with surface soils and were prepared principally from data available from the Department of Agriculture county soil surveys. Table 3 is additional engineering properties of the surface and subsurface.

42. Table 1 identifies the four soil types that occur within the eight mapping units and describes the ranges of the physical characteristics in terms of grain size, Atterberg limits, and permeability.

43. Table 2 presents the landforms, mode of deposition, range and predominant soil type, and the distribution of grain size in percent. Table 3 is keyed to the soil map (Plate 9) and presents the physical characteristics of each map unit. Although the floodplain environments reflect similar modes of deposition for all the landforms (except lacustrine), two or more soil types occur within each landform type. To assist the user, a predominant soil type has been identified, and a composite of grain-size distribution in percent has been presented. The geographic location of each soil type within each landform can be determined from overlaying Plates 3 and 9. In contrast to the floodplain, the upland is dominated by only two soil types. A brief description of the surface soil texture is presented in Table 2.

44. Table 3 presents the engineering properties of soils by depositional environment. Information contained in the table reflects the consideration of the engineering properties of soils as indicated on boring logs and laboratory test results. The table specifies the important engineering characteristics of soils with depth of the abandoned channel, chutes and bars, point bar, backswamp, alluvial fan, tributary valley alluvium, and loessial uplands. No interpretation of the specific engineering properties of undifferentiated alluvium, lacustrine deposits, and local rock outcrops were made due to the lack of detailed engineering data necessary for evaluation of the geologic environment.

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Table 1

Physical Characteristics of Surface Soils

Map Unit*	Surface Soil Type	Percent Passing Sieve No.				Liquid Limit	Plasticity Index	Permeability** cm/sec
		4	10	40	200			
1	SM	100	90–100	50–100	15–49	10–45	NP-17	9.9×10^{-7}->2.8×10^{-6}
2	SM†	Same as Map Unit 1				--	--	--
	ML	Same as Map Unit 3				--	--	--
3	ML	100	100	85–95	70–95	35–45	10–16	2.8×10^{-7}-9.9×10^{-7}
4	ML†	Same as Map Unit 3				--	--	--
	CL	Same as Map Unit 6				--	--	--
5	CL†	Same as Map Unit 6				--	--	--
	ML	Same as Map Unit 3				--	--	--
6	CL	100	100	100	80–100	25–45	8–21	2.8×10^{-7}-2.8×10^{-8}
7	CL†	Same as Map Unit 6				--	--	--
	CH	Same as Map Unit 8				--	--	--
8	CH	100	100	95–100	90–100	50–85	30–55	<2.8×10^{-8}

* From Plate 8.
** Dominant soil type.
† Permeability as measured by the SCS method.

Table 2. Landform, Origin, and Grain Size Distribution of Surface Soils

Location Environment - Landform	Mode of Deposition	Map Unit	USCS Type Range	USCS Type Predominant Surface Soil Type	Distribution of Grain Size (Percent) 0 — 25 — 50 — 75 — 100	Surface Soil Texture
Floodplain						
Fan	Fluvial	3, 4, 5, 6 & 8	SM ML to CH	ML (3)	C | Si | S | O	Rework loess: silts (ML) and silty clays (CL) with some silty sands (SM) and minor amounts of highly plastic clays (CH) with low amount of organics.
Abandoned channel	Fluvial	1 - 8	SM to CH	CH (8)	C | Si | S | O	Heterogeneous mixture of highly plastic clays (CH) to medium plastic clays (CL) with varying amounts of silts (ML) and silty sands (SM) in neck areas.
Backswamp	Fluvial	1, 2, 4, 5, 6, 7, & 8	SM to CH	CL (6)	C | Si | S | O	Predominantly silty clays (CL) and highly plastic clays (CH) with appreciable amounts of silts (ML) and minor amounts of silty sands (SM).
Chutes and bars	Fluvial	1 - 8	SM to CH	SM (1)	C | Si | S | O	Sand-silt mixtures (SM) in the bar areas and becoming more clayey (CL & CH) in the chutes.
Point bar	Fluvial	1 - 8	SM to [illegible]	CL/CH (7)	C | Si | S | O	Generally of equal distribution of silty clays (CL) and plastic clays (CH) with high quantity of silts (ML) and some silty sands (SM).
Tributary valley alluvium	Fluvial	5, 6	CL/ML to CL	CL/ML (5)	Insufficient Data	Rework loess: Silty clays (CL) and silts (ML) transported from uplands to valley bottom.
Lake	Glacial & lacustrine	6	CL - ML	CL (6)	Insufficient Data	Very thin interbeds of clays (CL) and silts (ML).
Uplands						
Loess	Aeolian	4, 6	ML/CL	ML (4)	C | Si | S | O	Silt (ML) with sand and clay sizes.

O - Organics; C - Clay (0.005 mm); Si. - Silt (0.005-0.074 mm); S - Sand (0.074 mm)

Table 3

Engineering Properties of Soil

Depth(ft): 0, 10, 20, 30, 40, 50, 60

Abandoned Channel	Point Bar	Chutes and Bars	Backswamp	Alluvial Fans	Tributary Valley Alluvium	Loessial Uplands
C(M-H) F(M-H) FV(S-M) E(M-H) S(M-H) WT(M) CP(M-H) ER(M)	Fill material (cinders, rocks, debris)	C(M-H) E(S) CP(S-H) D(S-M) F(M-H) S(S) ER(M-H) EV(S-M)	C(M) S(H) E(M) ER(M) CP(M-H) EV(H) D(S) FV(M-H) F(M-H) WT(M)	C(M) E(S) CP(S-H) D(S-M) F(M-H) S(M)	C(M) S(S) E(S-M) ER(S-M) CP(S-H) EV(S-M) D(S-M) FV(S) F(S-M) WT(H)	C(S-H) E(S) CP(M-H) D(S-M) F(M-H) S(S-H) ER(H) EV(S-M)
D(S) EV(M)	C(S) F(M-H) FV(M-H) E(S-H) S(H) WT(S-M)	FV(M) WT(M-H)	C(S-M) S E(S-M) ER(S) CP(S-M) EV(M) D(S) FV(S-M) F(M) WT(M-H)	ER(M-H) EV(M) FV(M) WT(M)	C(M) S(M)	FV(S-H) WT(S)
C(M-H) S(M)	CP(S-M) ER(S) D(S) EV(M-H)	C(S-H) E(S) CP(H) D(H) F(S) S(M) ER(S) F(S) WT(H)	substratum sands	substratum sands	E(S-M) ER(S) CP(M-H) EV(M) D(S) FV(M) F(S-M) WT(H)	C(S-M) E(S) CP(S-H) D(S-M) F(M-H) S(S-H) ER(H) EV(S-M)
E(M-H) ER(S) CP(M-H) EV(S-M) D(S) FV(S-M) F(M-H) WT(M)	C(S-M) E(S) CP(H) D(S-M) F(S-H) S(M) ER(M)	S(M) ER(H) EV(M) FV(M-H)				FV(S-H) WT(S)
C(M-H) E(M-H) CP(M)	EV(M) FV(M-H) WT(M-H)	substratum sands				
D(S) F(M) S(S) ER(S) EV(S-M) FV(S) WT(H)	substratum sands					
C(M) F(M-H) FV(-						
E(S) S(S) WT(H) CP(M) ER(S-M) [illegible](S-M) EV(S-M)						
substratum sands						

Substratum Sand*	
C(S)	S(M)
E(S)	ER(S)
CP(M)	EV(P)
D(H)	FV(H)
F(S)	WT(H)

Extends to base of valley

Dashed lines represent the minimum thickness of soil units within each [illegible] environment

Solid lines represent typical thickness of soil units within each [illegible] environment

* Engineering properties of substratum sand [illegible] is indicated

Symbol	Engineering Properties	Definition
C	Compressibility	Degree of consolidation
E	Expansion	Degree of swell
CP	Compactibility	Ease of compacting material to desired densities
D	Internal Drainage Characteristics	Ease at which material drains (permeability)
F	Frost Heave Potential	Susceptibility of material to movement by frost action
S	Slope stability	Stability of material on moderate slopes
ER	Erosivity	Potential of erosion of material
EV	Embankment value	Value for use in embankments (especially levees)
FV	Foundation value	Value for use as foundation material
WT	Water table influence	Susceptibility of the material to significant influence by water table fluctuations
(S) (M) (H)	Slight (or poor in EV, FV) Moderate (or fair in EV, FV) High (or good in EV, FV)	Modifiers indicating nature of the material for certain engineering characteristics

UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION	TYPE	LETTER SYMBOL	TYPICAL NAMES
COARSE GRAINED SOILS — GRAVELS	CLEAN GRAVEL	GW	GRAVEL, Well Graded, gravel-sand mixtures, little or no fines
		GP	GRAVEL, Poorly Graded, gravel-sand mixtures, little or no fines
	GRAVEL WITH FINES	GM	SILTY GRAVEL, gravel-sand-silt mixtures
		GC	CLAYEY GRAVEL, gravel-sand-clay mixtures
COARSE GRAINED SOILS — SANDS	CLEAN SAND	SW	SAND, Well-Graded, gravelly sands
		SP	SAND, Poorly-Graded, gravelly sands
	SANDS WITH FINES	SM	SILTY SAND, sand-silt mixtures
		SC	CLAYEY SAND, sand-clay mixtures
FINE GRAINED SOILS	SILTS AND CLAYS LL < 50	ML	SILT & very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
		CL	LEAN CLAY, Sandy Clay, Silty Clay, of low to medium plasticity
		OL	ORGANIC SILTS and organic silty clays of low plasticity
	SILTS AND CLAYS LL > 50	MH	SILT, fine sandy or silty soil with high plasticity
		CH	FAT CLAY, inorganic clay of high plasticity
		OH	ORGANIC CLAYS of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		Pt	PEAT, and other highly organic soil
WOOD		Wd	WOOD
SHELLS		SI	SHELLS
NO SAMPLE			

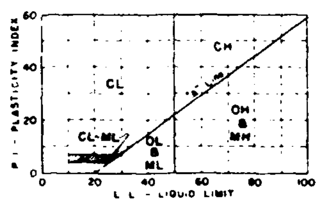
NOTE Soils possessing characteristics of two groups are designated by combinations of group symbols

DESCRIPTIVE SYMBOLS

COLOR	SYMBOL
TAN	T
YELLOW	Y
RED	R
BLACK	Bk
GRAY	Gr
LIGHT GRAY	lGr
DARK GRAY	dGr
BROWN	Br
LIGHT BROWN	lBr
DARK BROWN	dBr
BROWNISH-GRAY	brGr
GRAYISH-BROWN	gyBr
GREENISH-GRAY	gnGr
GRAYISH-GREEN	gyGn
GREEN	Gn
BLUE	Bl
BLUE-GREEN	BlGn
WHITE	Wh
MOTTLED	Mot

CONSISTENCY FOR COHESIVE SOILS

CONSISTENCY	COHESION IN LBS/SQ FT FROM UNCONFINED COMPRESSION TEST	SYMBOL
VERY SOFT	< 250	vSo
SOFT	250 - 500	So
MEDIUM	500 - 1000	M
STIFF	1000 - 2000	St
VERY STIFF	2000 - 4000	vSt
HARD	> 4000	H



PLASTICITY CHART

For classification of fine-grained soils

MODIFICATION	SYMBOL
Traces	Tr-
Fine	F
Medium	M
Coarse	C
Concretions	cc
Rootlets	rt
Lignite fragments	lg
Shale fragments	sh
Sandstone fragments	sdy
Shell fragments	slf
Organic matter	O
Clay strata or lenses	CS
Silt strata or lenses	SiS
Sand strata or lenses	SS
Sandy	S
Gravelly	G
Boulders	B
Slickensides	SL
Wood	Wd
Oxidized	Ox
Crumbly	Cr
Loose	Lo
Vegetation	Veg

NOTES
FIGURES TO LEFT OF BORING UNDER COLUMN "W OR D_{10}"[a]
Are natural water contents in percent dry weight
When underlined denotes D_{10} size in mm[a]
FIGURES TO LEFT OF BORING UNDER COLUMNS "LL" AND "PL"
Are liquid and plastic limits, respectively
SYMBOLS TO LEFT OF BORING
∇ Ground-water surface and date observed
(C) Denotes location of consolidation test**
(S) Denotes location of consolidated-drained direct shear test**
(R) Denotes location of consolidated-undrained triaxial compression test**
(Q) Denotes location of unconsolidated-undrained triaxial compression test**
(T) Denotes location of sample subjected to consolidation test and each of the above three types of shear tests**
FW Denotes free water
FIGURES TO RIGHT OF BORING
Are values of cohesion in lbs/sq ft from unconfined compression tests
In parenthesis are driving resistances in blows per foot determined with a standard split spoon sampler (1⅜" ID, 2" OD) and a 140 lb driving hammer with a 30" drop
Where underlined with a solid line denotes laboratory permeability in centimeters per second of undisturbed sample
Where underlined with a dashed line denotes laboratory permeability in centimeters per second of sample remoulded to the estimated natural void ratio

* The D_{10} size of a soil is the grain diameter in millimeters of which 10% of the soil is finer, and 90% coarser than size D_{10}

** Results of these tests are available for inspection in the U.S. Army Engineer District Office, if these symbols appear beside the boring logs on the drawings

GENERAL NOTES

While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of the region are anticipated and, if encountered, such variations will not be considered as differing materially within the purview of clause 4 of the contract.

Ground-water elevations shown on the boring logs represent ground water surfaces encountered on the dates shown. Absence of water surface data on certain borings implies that no ground water data is available but does not necessarily mean that ground water will not be encountered at the locations or within the vertical reaches of these borings.

Consistency of cohesive soils shown on the boring logs is based on driller's log and visual examination and is approximate, except within those vertical reaches of the borings where shear strengths from unconfined compression tests are shown.

SOIL SYMBOLS

Figure 1. Soil symbols

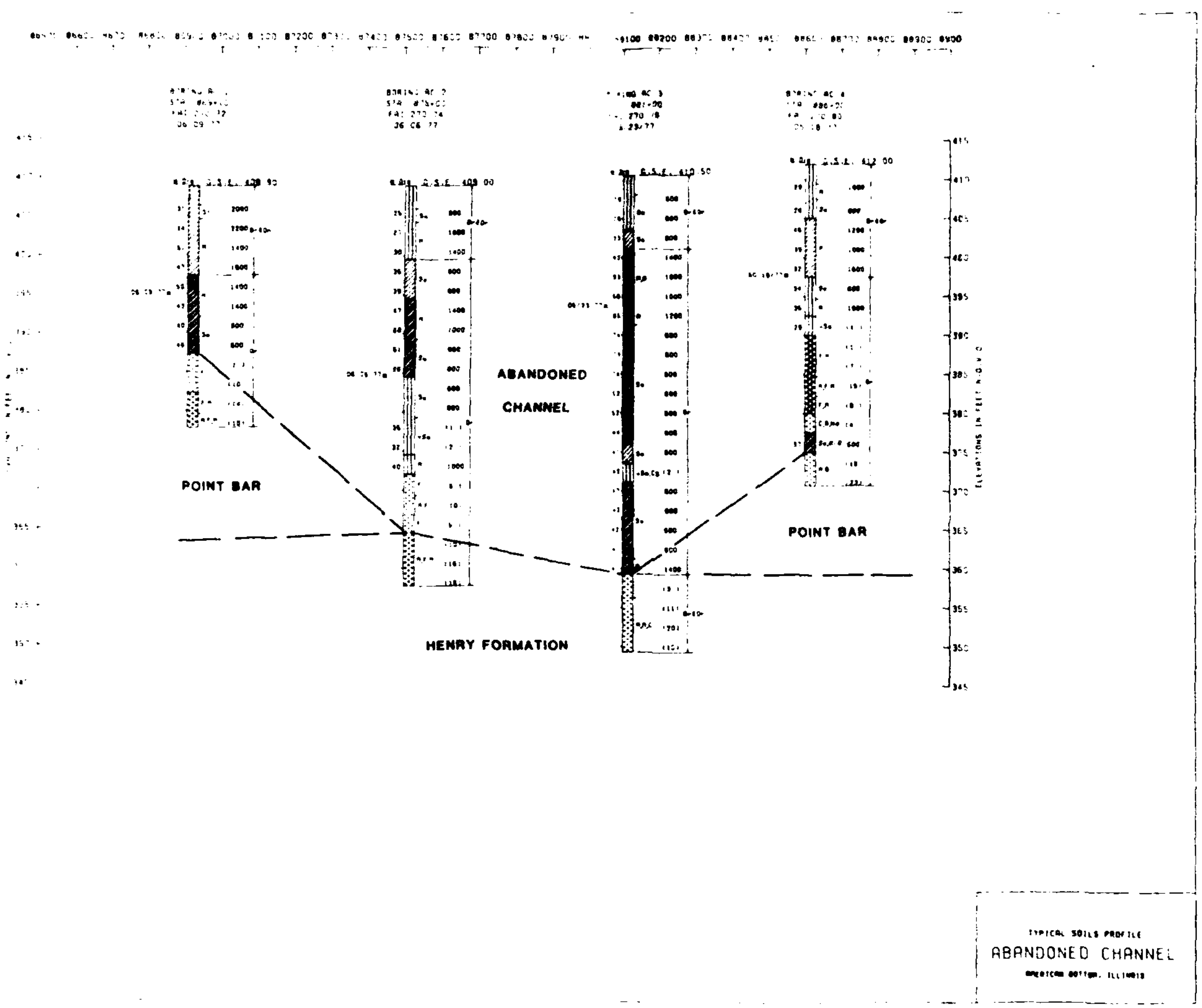


Figure 2. Typical soils profile, Abandoned Channel

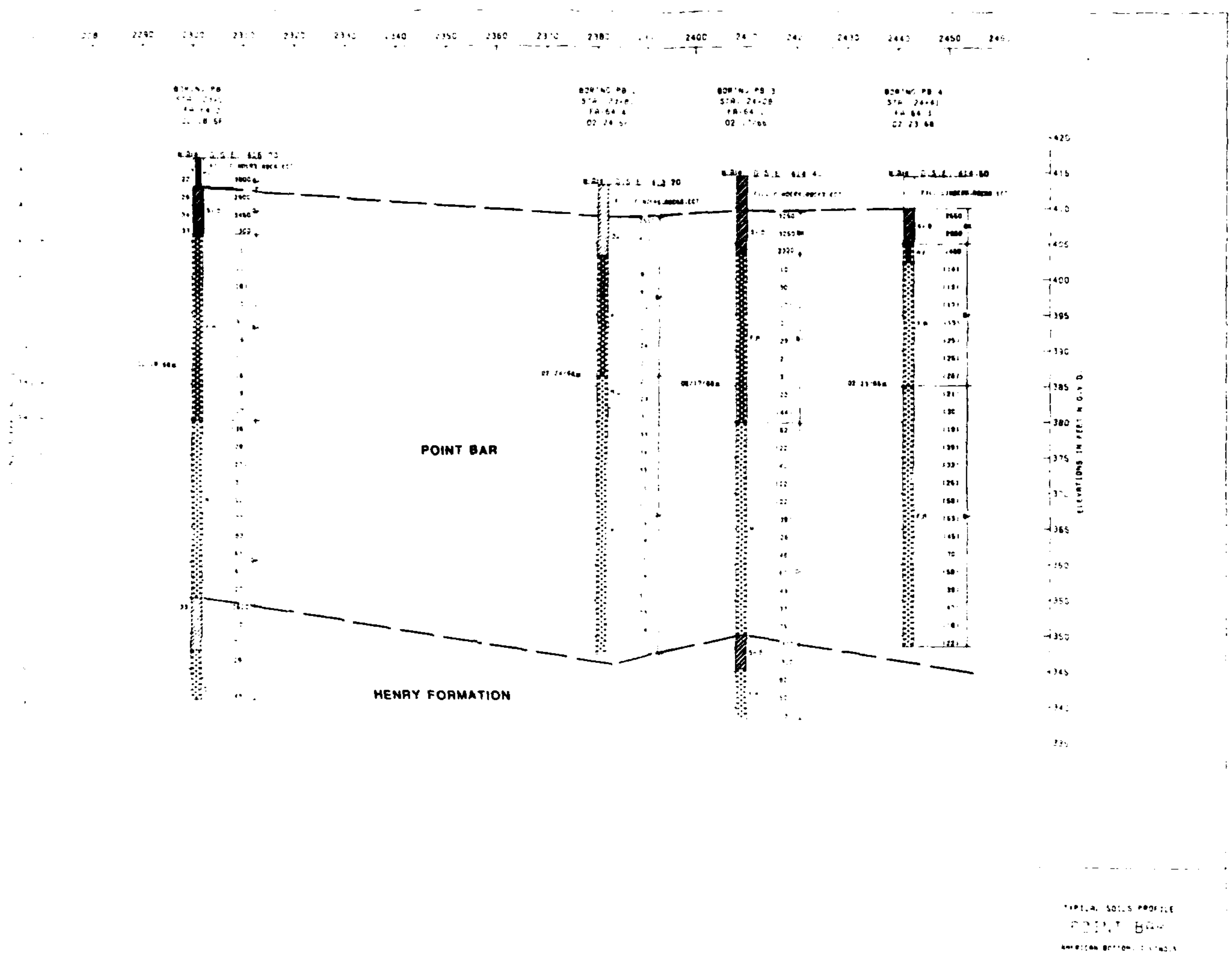


Figure 3. Typical soils profile, Point Bar

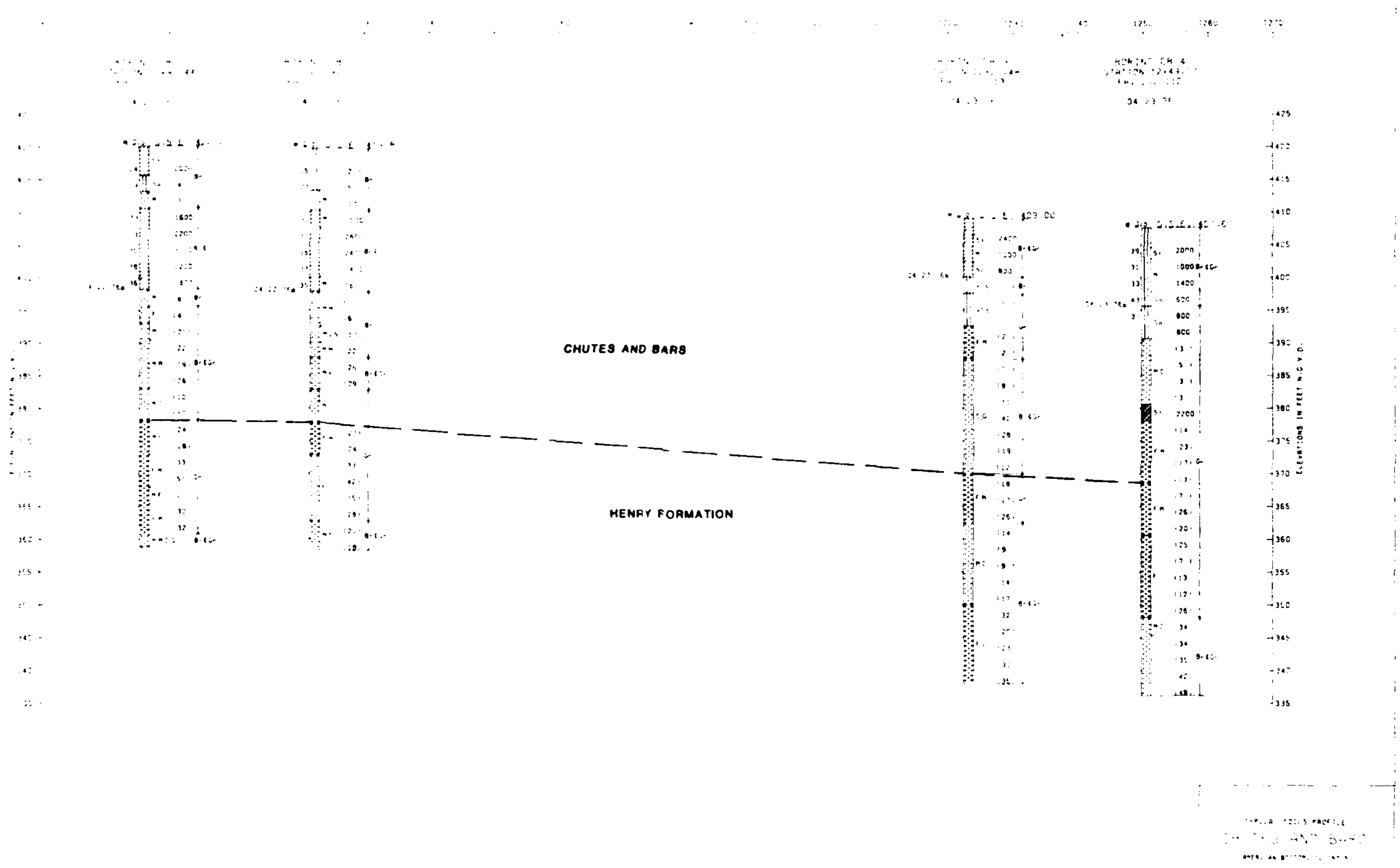


Figure 4. Typical soils profile, Chutes and Bars

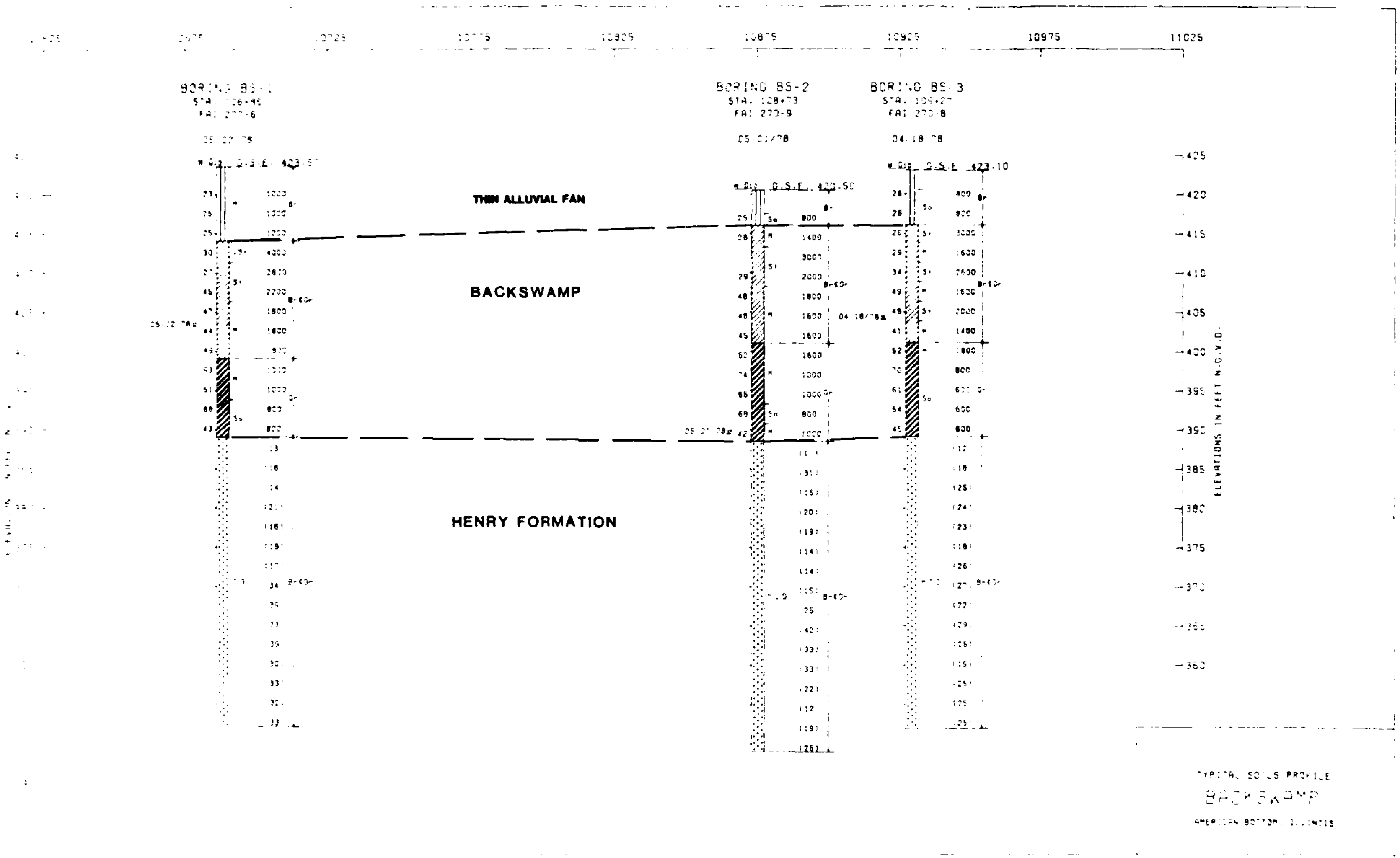


Figure 5. Typical soils profile, Backswamp

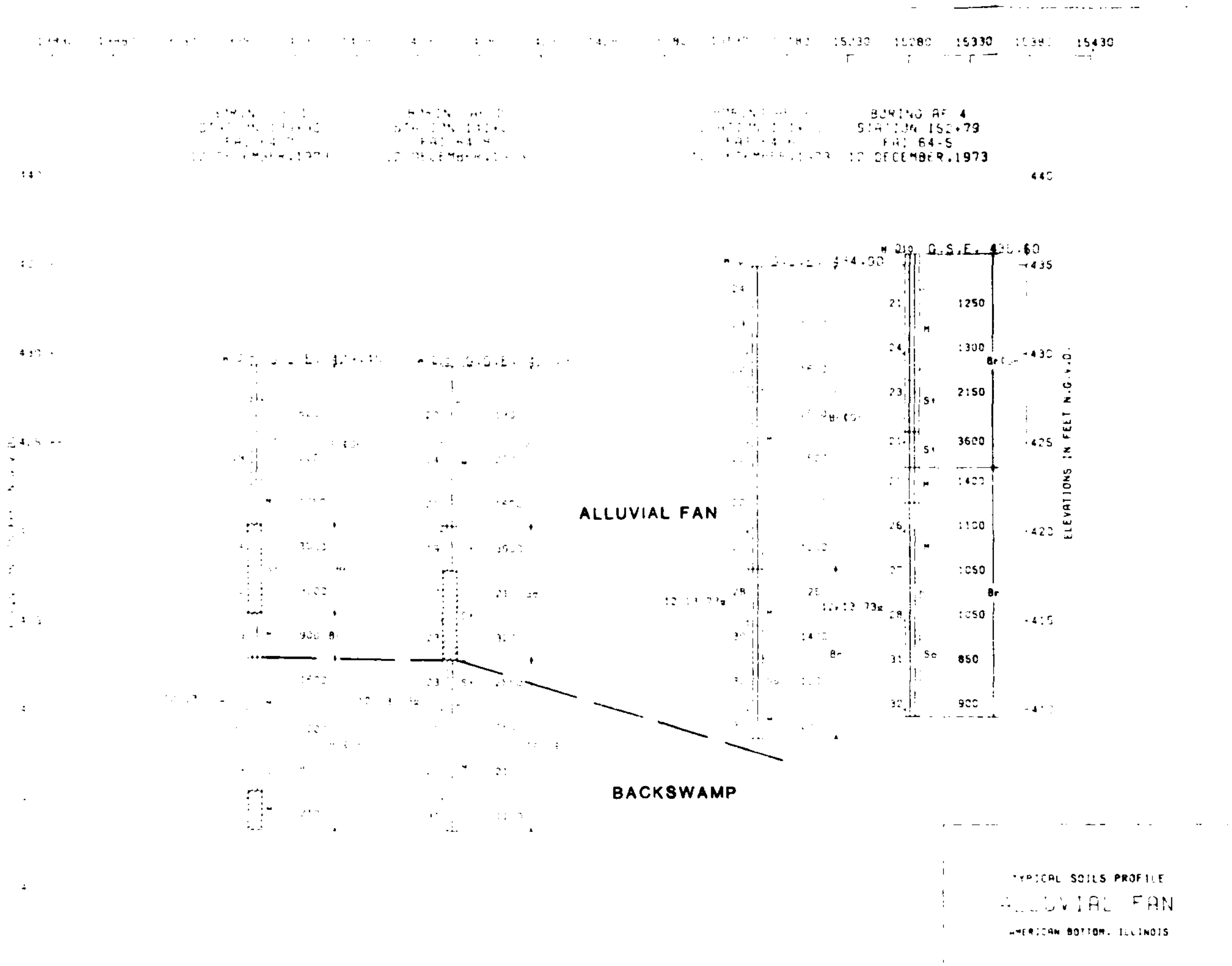


Figure 6. Typical soils profile, Alluvial Fan

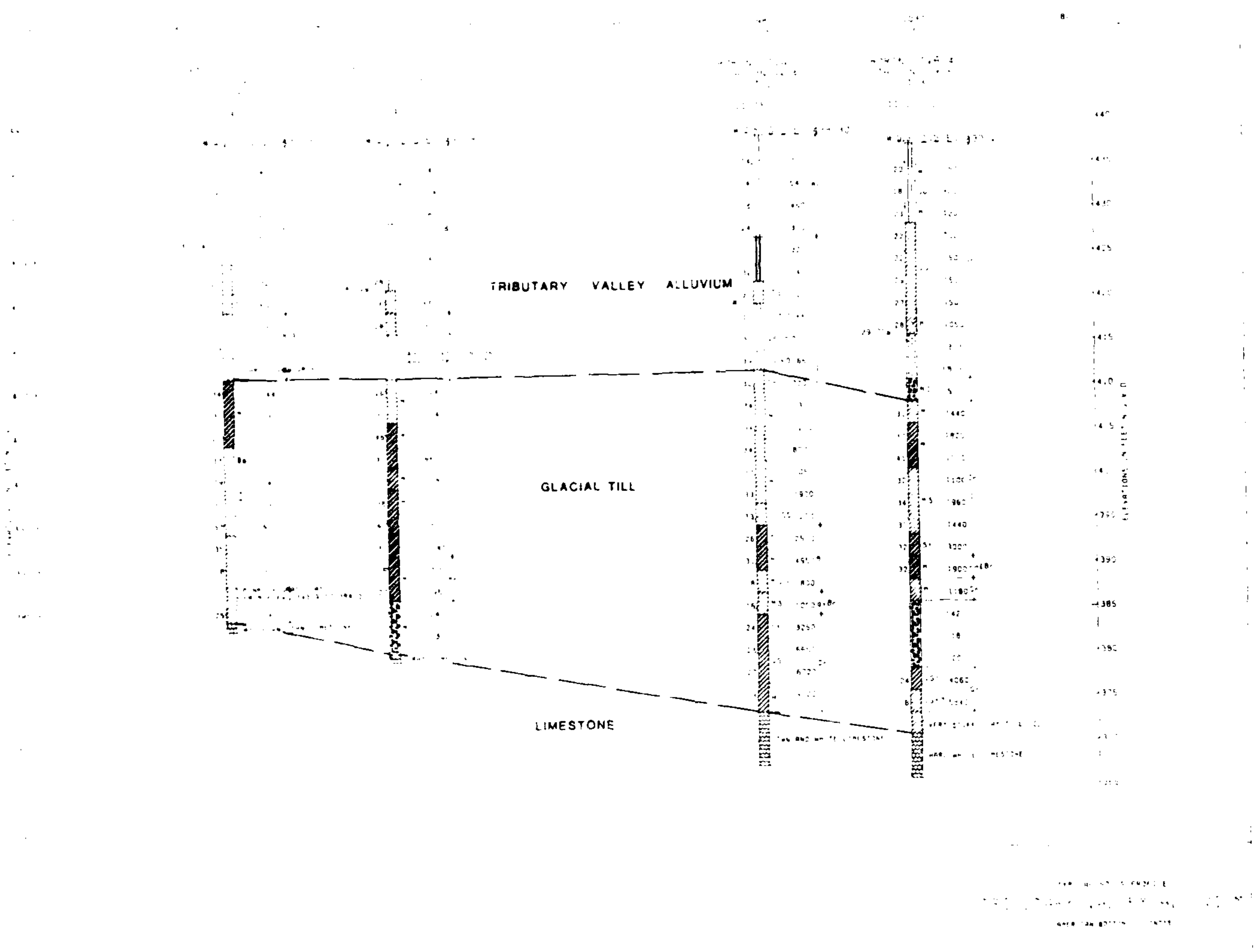


Figure 7. Typical soils profile, Tributary Valley Alluvium

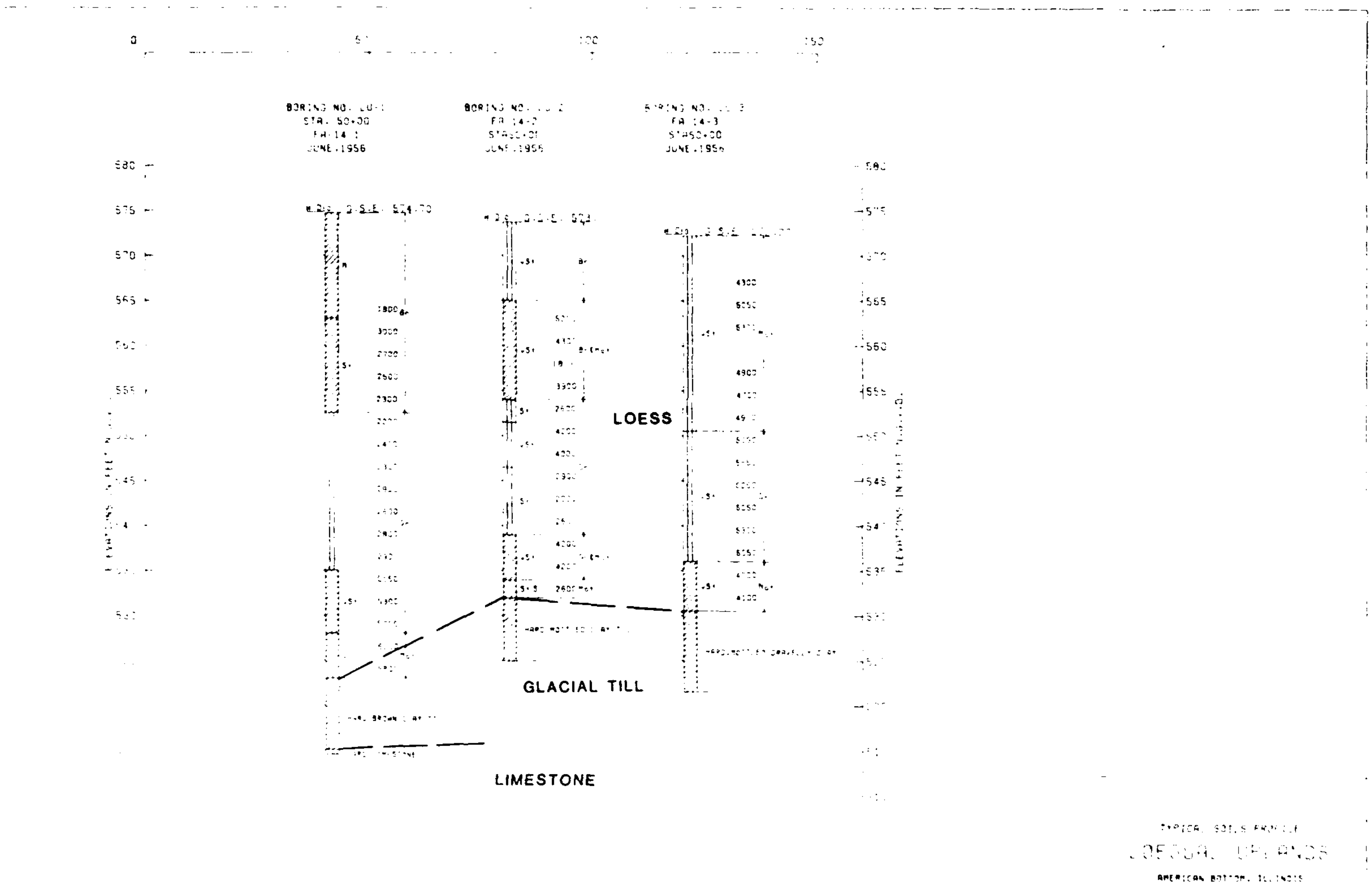


Figure 8. Typical soils profile, Loessial Uplands

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